Mathematics and War

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Mickey Flies the Stealth

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This article describes in a vivid and popular way the intimate relationship between mathematics, computer graphics, entertainment and warfare.

Entertainment, mathematics and war: what a strange trio! The mixture of brilliance and glory, brutality and suffering that inheres in its story would require an Aeschylus to get the proportions right.

I recently attended a large conference of the Society for Industrial and Applied Mathematics, an international organization. The range of topics discussed by the conferees was enormous, going from fluid dynamics to biomathematical problems to econometrics to computer vision to mathematical cryptography. A major talk by Christoph Bregler on computer animation of human movements including facial expressions feeds right into the needs of this strange trio.

In talking to the conference participants, I learned that the *marriage* of war, mathematics and entertainment is now taken for granted just as they take for granted the marriage of entertainment, mathematics and medical imaging. The link in both cases: computer graphics, animation, and the formation of virtual objects.

The threefold combination first entered my consciousness forcibly when I read a 1997 report of the National Research Council entitled *Modeling and Simulation*: *Linking Entertainment and Defense*. This report was based on a workshop held in October 1996 that was attended by people from the film, video game, and theme-park industries and also by people from the defense department and their contractors. The object of the conference was to discuss common interests and how they might help each other.

The notions of entertainment, mathematics, and war together with their ambiguities and misapprehensions, are sufficiently understood so I shall build up to the threefold combination in stages by beginning with the twofold.

Mathematics and entertainment: This combination is ancient. Simple puzzles or games of chance and of strategy often have a mathematical underlay. More recently, sports of all kinds have experienced increasing mathematization through the accumulation of statistics and the decisions based on them. Mathematics itself

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is often considered a game. In his introduction to Johan Huizinga's famous *Homo Ludens: a Study of the Play Element in Culture*, George Steiner wrote

> Of all human activities – particularly pure mathematics – comes closest to Huizinga's own standards of elevated play.

In education, mathematics is often promoted on the basis that "mathematics can be fun". Computer graphics, which, as we shall see, has a substantial mathematical base, is used for the simulation of humans and environments, both static and animated, and is combined with very elaborate and sometimes interactive story lines.

Mathematics and War: This also is very old, going back at the very least to Archimedes (220 BC). Niccolo Tartaglia (*La Nova Scientia*: 1537) wrote on the mathematical science of ballistics and warned that such knowledge, if widely known, could be dangerous. Since the beginning of the 20th Century, war has become increasingly mathematized in all its aspects and research in both pure and applied mathematics have been supported in a great measure out of governmental offense/defense budgets.

War and Entertainment: Today's computer games are mostly simulated battles. Though virtual war flourishes via the computer, it did not require the computer to link war and entertainment. Homer was one of the first to provide the mix. Think of the gladiators in the Roman arenas or the mock naval battles that amused the court of the French Louies. Comic books are filled with war situations. Live reenactment of old battles currently flourishes. I recently saw on TV a reenactment of a 10th Century battle in Ireland, in full costume, between the Irish and the Vikings. Spectators were watching the engagements from the sidelines while the children ate ice cream.

> Ever since words existed for fighting and playing, men have been wont to call war a game. [Huizinga]

Combining all three elements we have: Entertainment, mathematics and war: Though it would be easy to give simple examples from antiquity, chess for example, I'll limit my discussion to recent instances where the possibility of applications to armed conflict is the principle motivation. The link I want to stress is simulated actions and environments achieved through computer graphics. On the entertainment side, computer graphics appear increasingly in Hollywood productions. Many of us have seen *The Perfect Wave*. Computer graphics is used increasingly for military instruction and strategic matters. And computer graphics is solidly based on mathematical theories and constructions (algorithms) combined with incredible developments in computer hardware.

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What precisely are the areas of overlap between entertainment and defense? The principal ones, according to the 1997 report of the National Research Council are

1. Virtual reality technologies; the creation of simulated immersive environments against which defensive-offensive action takes place.
2. Rapid communication between many – possibly thousands – of simultaneous players (i.e., combatants).
3. Computer-generated characters "that model human behavior in activities such as flying an aircraft, driving a tank, or commanding a battalion such that the participants cannot tell the difference between a human-controlled force and a computer-controlled force."

What are the differences between the entertainment and the military cultures? The goal of the military is to win battles, to defend one's country. The goals of entertainment are to create products that capture the public's imagination strongly, hook the public on such products, and make money. But, according to Capps, McDowell, and Zyda of the Naval Postgraduate School, the final products of both groups are "ultimately judged on immersiveness, ease of use and realism."

It would appear that with the investment of billions of dollars in computerized filmography and video games, the entertainment industry has been ahead of the military in all three of the above areas of mutual interest despite the computer sophistication of the military. E.g., the Internet was initially a military communication arrangement that rapidly exploded into worldwide usage and misusage.

The military therefore can communicate its simulation needs to the entertainment world and subcontract for the latter's specialized products – a very good thing for sales. Reciprocally, assuming freedom of communication, the computer entertainment world can benefit from the techniques developed independently by the military.

Simulated warfare can be bought or downloaded from the web and played. According to Capps, McDowell and Zyda, "the Navy recently began training prospective student aviators using a commercial off-the-shelf- flight simulator and found that it improves their performance." While the general goals of the trio of war, mathematics and entertainment are in the open literature, the mathematical or programmatic details of products are either company or militarily confidential.

The principal computer games have scripts that set up conflicts between the human player or numerous other players and the computer. The rules of engagement can be made as complex as desired. Thus, a description (you can find it on the Web) of a game called *Mech Commander 2* says, in part

> On the full 3D (three dimensional) battle field, you will control movement, targeting, and engagement tactics of your mechs [i.e., equipment]. Call in support elements such as artillery or air strikes, scout choppers and sensor probes, even a salvage team to salvage downed mechs. Capture resource buildings or resource trucks for more 'support points'…. It's all up to you.

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Torsdag den 29 augusti, kl 19:00

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Kontakta : Charlyne de Gosson, e-mail: cdg@bth.se

Figure 1. On the first evening of the *International Scientific Meeting on "Mathematics and War"*, organized by Prof. de Gosson of Blekinge Institute of Technology and held in the historic Swedish military port of Karlskrona, August 29–31, 2002, the author gave a public lecture in the local Naval Warfare Museum. [Courtesy: Ch. de Gosson]

The military can outline its own specialized scenarios for training or logistical purposes, e.g., dealing with an ambush, freeing hostages. In order to make a forceful training impact, the virtual environment against which the scenarios are played must be tremendously realistic. Game producers are now talking about "haptic" applications (i.e., pertaining to the sense of touch) that go beyond sight and sound by wiring the players. Even without such advanced technology, cyberartists have been able to produce violent reactions such as nausea or convulsions in viewers.

The achievement of realism has a strong mathematical base. In modeling: The characters in computer games (people, equipment, are built from graphical prototypes, such as spheres and cylinders. Other primitives are built up from meshes and mathematical spline curves, the latter having been developed during World War II and saw early employment in the design of airplane, ship, and automobile surfaces. I understand from talking to mathematical technologists in the auto industry that this industry now does a good fraction of its design work using graphic packages and immersion into virtual reality constructions.

In articulation and animation: Motion through space is guided by mathematically defined spline curves. Differential calculus applied to the spline curves can, for verisimilitude, determine e.g., how to compute the direction of the tires in a moving truck. Martha Gregg and Paul Davis note how a realistic image of the surface of a waving flag is made:

> A sine wave plus noise is imposed on the vectors normal to the triangular mesh elements defining the surface.

In shading and reflections: These use textured micropolygons and surface normals. Capps, McDowell and Zyda point out that producers are claiming 66 million textured polygons per second, whereas 4.8 billion are required to make computer images absolutely indistinguishable from reality. It is predicted that advances in computer hardware will reach this goal shortly.

I would like to add parenthetically, that my field as a professional mathematician is known as "approximation theory". This concerns itself with the representations of arbitrary curves or data through mathematical formulas. By training up students in the techniques of this field, I had a small finger in the early development of CAGD (computer aided geometric design). At the time I could hardly have foreseen the widespread uses of this mathematical technology.

The triangle is now closed: mathematics-entertainment-war-mathematics, and we can move back and forth around its sides. The products of these links can be employed for military training on the ground, in the air, or on the sea, or for the study of strategic and tactical alternatives.

For recreational purposes, the links can provide history buffs or partisans with the ability to sit in front of their terminals and by merely clicking, refight the Peloponnesian War, the Battle of Lepanto or the capture of Paschendaele (a half million lives lost in three months), all made realistic by mathematical modeling. Virtual casualties in their last agonies can be strewn about a 3D landscape by random number generators. The line between real and virtual war becomes more and more blurred. The Great Computer Game becomes a military training ground or a Grand Guignol Theatre with audience participation.

Could the virtual ever replace the real? If simulated and networked military engagements, played over and over again, resulted in the virtual destruction of most players, then some small measure of sense might seep into the collective brain of humanity. Could we achieve through mathematical simulation what the humane philosopher William James sought for and despaired of finding: a moral equivalent of war. Could we achieve the dream of Leibniz: that if a dispute arose we would standardly say: let us compute. This would indeed be the glory of mathematics.

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